Green technology with geosynthetics prevent environment from railway dangerous pollutants

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ABSTRACT: In the paper the problem of the railway ballast pollution by heavy metals is considered. Heavy metals migrate into the soil under the action of precipitation and acid rain. Environmental pollution caused by heavy metal ions is particularly hazardous. Unlike other pollutants in soils, the heavy metal ions reserve for a long time even after removal of the pollution source. The heavy metal ions ability to migrate to the soil into the underground, ground and surface water, to accumulate in food leads to the need of consideration of their impact on human health.
The problems of contaminated surface water treatment near railway bed are examined in this study. To solve this ecological problem we offer systems that have geoecoprotective properties against heavy metal ions. This structure consists of geoecoprotective materials, gabions and geosynthetics.
Geoecoprotective technology involves the use of gabion constructions, which are filled by different stone placeholders in the process of construction and installation work.
The main tasks of the work is to determine the geoecoprotective properties of the selected materials and using these materials in dispersion form in transport construction technologies with geosynthetics to protect the environment from harmful effects of heavy metal ions.

Keywords: geoecoprotective materials, geosyntetics, geomembrane, woven geotextile, heavy metals ions, railway transport

1 INTRODUCTION

The surface runoff flowing from the polluted roadbed has the greatest impact on the natural environment.

Contamination of storm and snow melt sewage water by oil products, suspended solids, heavy metals may reach environmentally dangerous levels (Ahmaruzzaman 2011, Svatovskaya et al. 2015, Lei et al. 2017, Umesh et al. 2017). Therefore, the pollution assessment and the choice of methods of sewage purification should be carried out during the design of roadway (Bogdanov 2001, Svatovskaya et al. 2015, Sakharova et al. 2016)

According to the above, the aim of this work was to develop a new type of local treatment plant to purify runoff from the road surface. The main purpose of this structure is the concentration reduction of heavy metals and oil products in storm sewage. This structure consists of gabions, filler and geosynthetics. The use of geoecoprotective materials as the main gabions filler is offered. Geoecoprotective materials are materials which consist of technogenic or artificial origin substances. Their composition is similar to the composition of the Earth's crust («earth» - «geo»), and they can be used to protect the Earth's geosphere shells (atmosphere, hydrosphere, lithosphere, and others.) from pollution.

The main objectives of the work is the study of geoenvironmental protective properties of various types of fillers against heavy metals and oil products and development of the method of laying them in the in the construction of local treatment plant.

As opposed to other pollutants heavy metal ions are kept in soils for a long time even when a pollution source is eliminated. Periods removal of heavy metals from soils are several thousand years (Bogdanov 2001). Heavy metals have the ability to migrate to the plant, into the lakes and rivers, groundwater and underground water and also they can accumulate in the food chain. Disorder of the cardiovascular system and the occurrence of severe allergies are the result of contact human with the pollutant. Most of the heavy metals have embryotropic and carcinogenic properties. They are genetic poisons that are accumulated in human body with a long-term effect.

Railway track is an integral part of the process of passenger and freight traffic, but also it is a natural and technogenic system that contributes to environmental pollution. The main part of contaminants get into the soil, and consequently, to ground and surface water by transportation cargoes by railways and, especially, during their rash or leakage. Oil products and heavy metals are the most dangerous for the environment.

There are some technical solutions to protect environment from heavy metal ions (Gates et al. 1993, Thornot 1994, Indraratna et al. 2010,2014, Sounthararajah et al. 2016).

The geosynthetic products most commonly used in roadway systems include geotextiles (woven and non-woven) and geogrids (biaxial and multiaxial), although erosion-control products, geocells, geonets (or geocomposite drainage products) and geomembranes have been incorporated in a number of applications (Zornberg and Thompson 2010, Petriaev 2015). These various types of geosynthetics can be used to fulfill one or more specific functions in a variety of roadway applications, including geoenvironmental protection.

2 GABION LOCAL TREATMENT PLAN

Geoecoprotective technology involves the use of gabion constructions, which are filled by different stone filler in the process of construction and installation work.

It is proposed instead of the standard gabion filler to use filler from investigated geoecoprotective materials such as cement clinker in dispersion form (see Figure 1). Such structure is arranged to release surface runoff, contaminated by heavy metal ions, from the tray along the road to the nearby river [16].

Figure 1. Gabion construction with stone and geoecoprotective loading.

Gabion structure will consist of three sections (see Figure 2). Standard stone filler fills the two external sections. The inner section is filled by filler of investigated material, which have geoecoprotective properties towards heavy metal ions. The inner gabion section surface is covered by nonwoven geotextile which have high filtration properties and filled by geoecoprotective materials.

The mineral geoantidot fraction in 1.25 ... 2.5 mm was chosen taking into account the real level of pollution in the rail transport. This is suitable for the optimum ratio of the culvert ability and polluted wastewater treatment efficiency.

The use of such local construction will allow to reduce or to minimize environmental heavy metal ions pollution accumulated in surface water and groundwater from the roadbed.

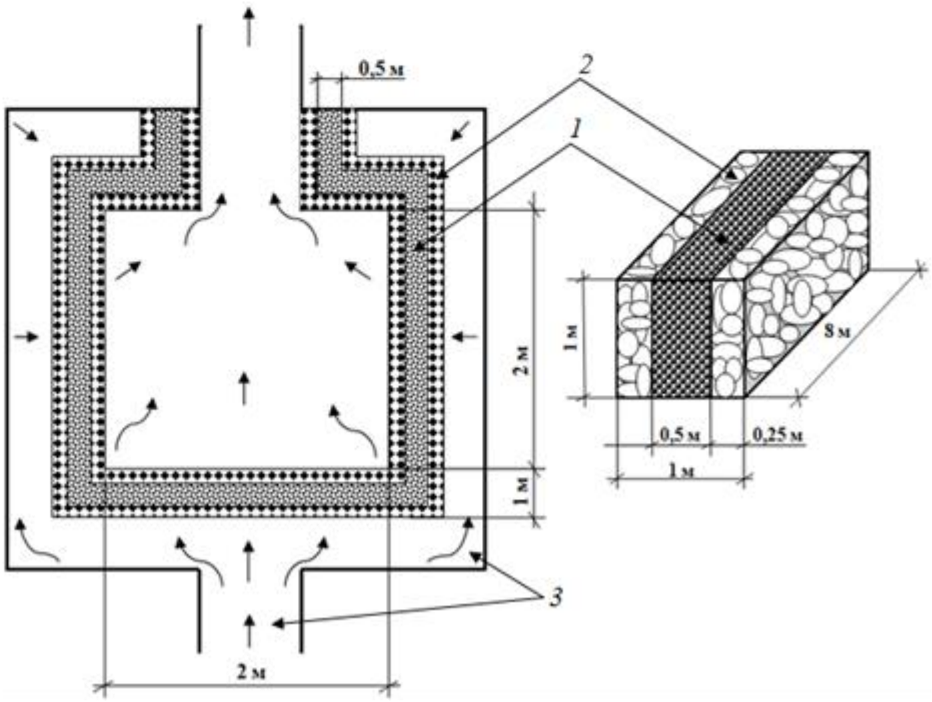

Figure 2. Local gabion treatment plant for surface runoff.

3 GEOECOPROTECTIVE TECHNOLOGY USING GEOCONTAINERS

The geoecoprotective materials are put along drainage gutters in the space out of geocontainers' walls. Passing through geoecoprotective material, polluted wastewater is purified before it gets into a gutter (see Figure 3). It is possible to use containers made of woven geotextile in which a geoecoprotective material can be placed.

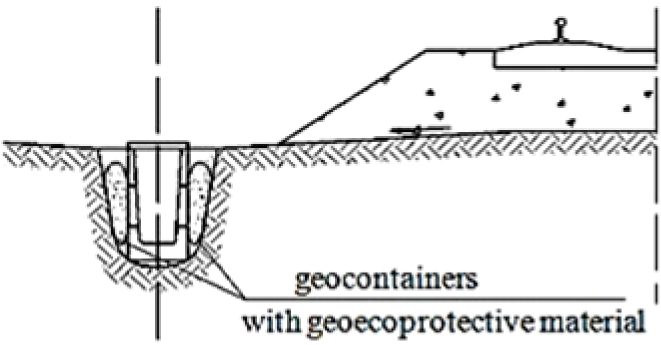

Figure 3. Geocontainer with geoecoprotective material.

This technology was introduced by October railway (St.Petersburg). Autoclave foam concrete of fraction 0.63…1.25 mm was used as a filler for geocontainers. This allowed reducing the concentration of lead ions in surface sewage from 0.0516 mg /l, which exceeded maximum allowable concentration (MAC) in 8.6 times to 0.0001 mg/l. Therefore, the treatment efficiency was 99.8 %.

4 UNDER BALLAST LAYER WHITH GEOECOPROTECTIVE PROPERTES

The geoecoprotective technology use the geomembrane [16, 17]. This solution is based on the mineral geoantidot laying under ballast. Existing ballast cleaning machine SCHU-800 or track machine AXM 800 (see Figure 4) can create such layer without removing of track rodding. Therefore, process technology can be carried out during the reconstruction or repair of railway track repairing.

Figure 4. Ballast cleaning machine SCHU-800 and track machine AXM 800.

The under ballast laying of geoecoprotective material will include the following technological operations [19]. Geoantidot or its mix with inert filler (sand) is filled in the gondola cars of the track machine. The mix is supplied from the gondola cars to the area which is located behind the excavation chain of the ballast cleaning machine on the geomembrane, unreeled from a roll in the repair track section. Then this mix is spread by means of screws on a designed width and thickness of sub ballast.

The mix is brought up to optimum moisture by spray irrigation using equipment, which is additionally installed on the ballast-cleaning machine. Regular surface vibrators of the machines SCHU-800 produce compacting of geoecoprotective under ballast layer. Reclaimed ballast is laid on the formed surface. Such geoecoprotective structure will provide ballast decontamination from heavy metals and others pollutants before they together with surface water get into the drainage system along the roadbed. The railway cross-section with geoecoprotective under ballast layer is shown in Figure 5.

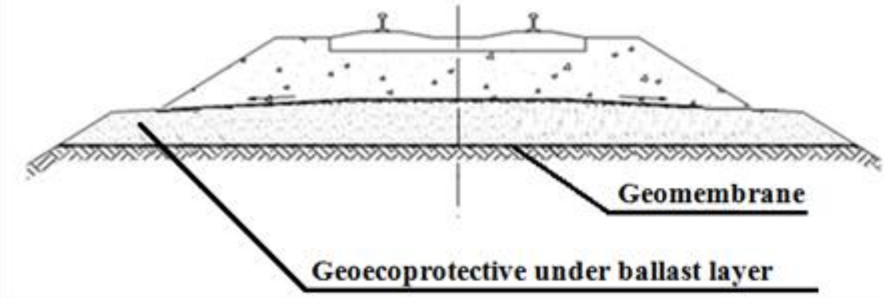

Figure 5. Railway track with geoecoprotective under ballast layer.

5 GEOECOPROTECTIVE TECHNOLOGY WITH THE USE OF GEOMEMBRANE

The use of building wastes or clinker together with a geomembrane is offered with subsequent technology of their laying into a track. In order to give the protective properties for the railway line we suggest using one of the test materials placed under subgrade shoulders by the track machine CZP 600. On the top of subgrade, a geomembrane diverting polluted water from the surface towards a subgrade shoulder is laid where it purifies water from heavy metals ions (Svatovskaya L. B., 2012). The railway track cross-section with this technical solution is presented in Figure 6.

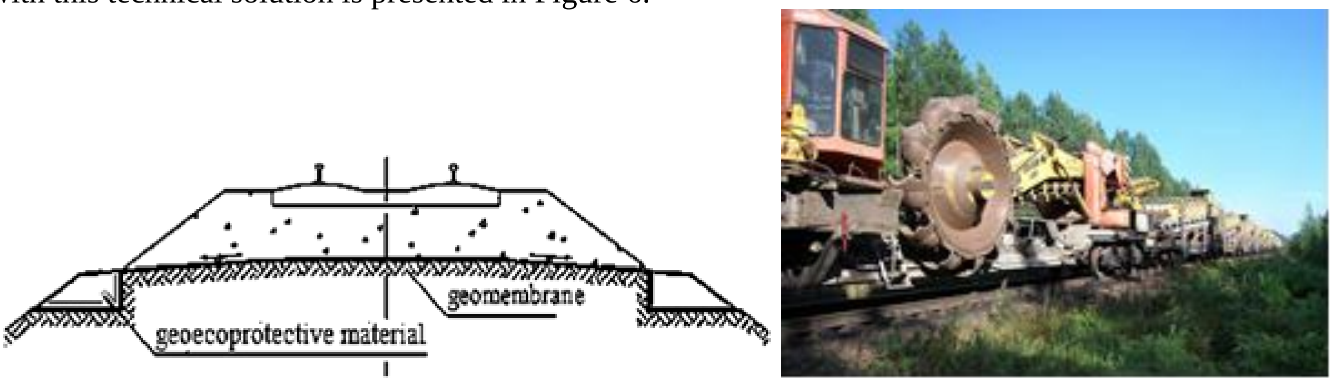

Figure 6. The railway track cross-section with geomembrane and the track machine CZP 600.

6 CONSTRUCTION WASTES RECYCLING

Crushed waste from the construction industry, particularly bricks or concrete can use to prevent environment from railway dangerous pollutants.

In this case, the garbage is not exported at a special polygon. Firstly, the concrete structures are crushed with special attachments – hydraulic breaker or shears, which are hung to the excavator, and then they are poisoned in the crushing machine Figure 7. The special separators (large magnets) which are built-in the crushing hopper, separate the remnants of the reinforcement and other metallic inclusions.

The crushed material of size from 0 to 120 mm is a result of fractionation. The fraction of 0.1-5 mm is suitable for the arrangement in the gabion inner layer or geocontainers filler, while the fraction 80-200 mm is suitable for external sections. Fraction 0,1-40 mm is used for the construction of under ballast layer or in the subgrade shoulder.

Figure 7. The crushing machine.

7 GEOECOPROTECTIVE PROPERTIES STUDY OF DIFFERENT MATERIALS

Geoecoprotective properties of clinker and some technogenic wastes are considered as ad- and absorbents of heavy metals ions. The department Engineering Chemistry and Natural Science, led by Professor L.B. Svatovskaya have being made such research during the past 20 years. Department scientists have identified geoecoprotective properties of materials such as non-autoclaved foam concrete, granulated blast-furnace slag, phosphogypsum, rubble-containing shungite, crushed concrete etc. (Svatovskaya et al. 2010).

For research 4 fractions of materials were selected: 0.14-0.315 mm, 0.315-0.63 mm, 0.63-1.25 mm, 1.25-2.5 mm. For this purpose, all the materials were pre- crushed in a mortar and sieved through a series of sieves with mesh size: 0.14 mm; 0.315 mm; 0.63 mm; 1.25 mm; 2.5 mm.

Researches on determination of geoecoprotective properties of artificially received and techno genic materials were carried out on model solutions of salts of heavy metals ions with concentration of 10^{-5}, 10^{-4} and 10^{-3} mol/L that exceeds maximum concentration limit by 200 times and more. For the model solutions containing heavy metals ions, the following salts were used: $Cd(NO_3)_2$, $Pb(NO_3)_2$ and $Cu(NO_3)_2$. Determination of the concentration of heavy metal ions in the solution before and after interaction with the test materials was performed on an electronic analyzer "Expert- 001" using a series of ion-selective electrodes ALICE (Cu (II), Cd (II), Pb (II)) (Fluid analyzer Expert – 001 2007). Volumetric flasks were filled with 100 ml of model solution containing heavy metal ions of different concentrations. Then the 1-gram test materials of various fractions poured the flasks. The suspension was stirred alternately every 5-10 minutes. The contact time was taken to 1 hour, based on the adsorption-desorption equilibrium establishment. After this time, the materials were separated from the test solutions on the filter paper, and the final concentration of heavy metal ions was determined in each sample. The reaction was spontaneous at an air temperature of 293 K.

8 LABORATORY EXPERIMENT RESULT

As Figure 8 shows, the technological and artificial silicates and hydrosilicates with initial polluting cation content up to 0.1 mmol/L. achieve the most effective polluted water decontamination. This cadmium concentration is 2000 times higher than the real cadmium pollution level on the railways.

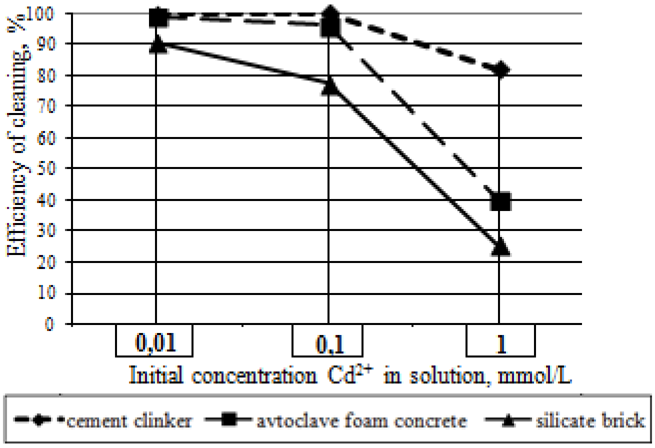

Figure 8. The dependence of the efficiency of cleaning solutions from the initial concentration of Cd^{2+} ions in solution (air temperature 293 *K*).

For the filter materials with grains dimensions from 0.1 to 2.5 mm the residual concentration of cadmium after the interaction with the test materials is increased at an initial ion concentration 10^{-3} mol/L (Fig.9), that supposes their geoecoprotective ability reducing (Svatovskaya et al. 2012a).

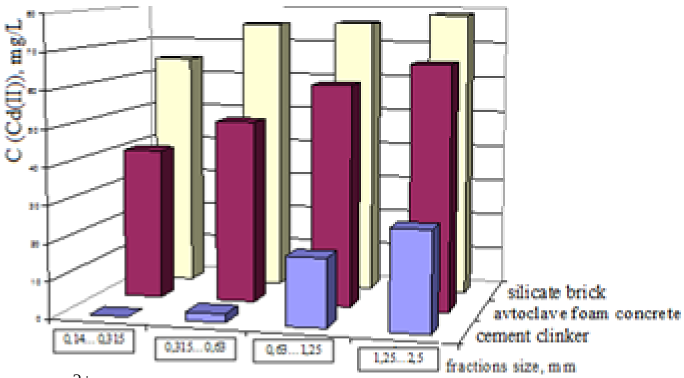

Figure 9. The dependence of the Cd^{2+} ions residual concentration in a solution of the test materials fineness (initial concentration 1 mmol/L, air temperature 25 ℃, contact time 1 hour).

Cement clinker is being shown to be the material for clearance take off water from heavy metal ions Figure 10 present the qualitative reaction results to the copper ions content in the solution with initial concentration 0.1 mmol/L after interaction with clinker.

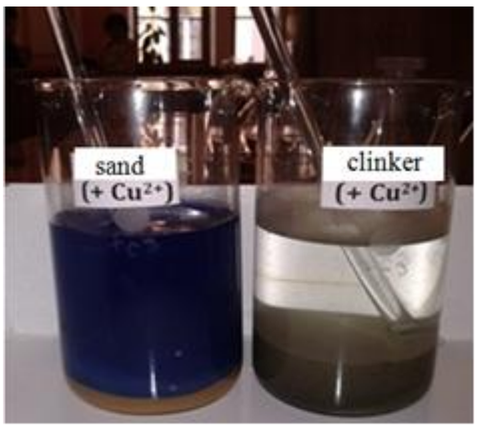

Figure 10. Results of experiments on the interaction of clinker and sand with solution containing copper ions (Cu^{2+}) with concentration 0.1 mmol/L.

The sand was taken for comparison as an inert material in relation to the heavy metal ions. As Figure 3 shows, the lack of characteristic coloring speaks that the free copper ions (Cu2+) is absent in the system «clinker – heavy metals ions solution».

Therefore, the use of recycled aggregates for geoenvironmental protective purposes can be considered the most successful example of waste management in the construction industry.

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